REFERENCE TO CO-PENDING APPLICATIONS

This application is a Continuation-In-Part of U.S. Patent Application No. 09/140,759 (now U.S. Patent No. 6,263,268), filed August 26, 1998 entitled SYSTEM AND METHOD FOR PROVIDING MOBILE AUTOMOTIVE TELEMETRY which claims the benefit of U.S. Patent Application No. 60/056,388, filed August 26, 1997 entitled SYSTEM AND METHOD FOR PROVIDING MOBILE AUTOMOTIVE and is a Continuation-In-Part of International Application Number PCT/CA98/00986, filed October 23, 1998 (which designates the U.S. and was published in English as International Publication Number WO 99/22497 on May 6, 1999) entitled TELECOMMUNICATIONS SYSTEMS, which claims benefit of U.S. Patent Application No. 60/063,218, filed October 23, 1997. This application also claims benefit of U.S. Patent Application No. 60/148,270, filed August 11, 1999 entitled VEHICULAR COMPUTING DEVICE and of U.S. Patent Application No. 60/187,022, filed March 6, 2000. All of the above-mentioned patents and patent applications are incorporated herein by reference.

BACKGROUND OF THE INVENTION

FIELD OF THE INVENTION

The present invention relates to data communications systems and more particularly to the field of vehicular telemetry using RF packet networks in conjunction with Internet or similar protocols.

DESCRIPTION OF THE RELATED ART

Hereinafter numerical reference is made to materials listed in Appendix A at the end of the disclosure.

Conventionally, vehicles have been known to exchange data with a diagnostic computer system (such as in a repair garage) over a hardwired or infrared data link, or a regulatory computer system (such as a toll highway) by a data link using a low power transponder.

More sophisticated vehicular telemetry for commercial fleets has been made possible in the last several years through satellite RF packet networks. In these vehicular telemetry systems, vehicle sensor data can be transported over wireless data links to a computer that is programmed to monitor and record automotive phenomena and to support database systems for vehicular maintenance, without the need for the vehicle to be in a particular service bay for example. However, these systems are relatively expensive to operate.

A considerable amount of research is being dedicated to developing feasible Intelligent Vehicle Highway Systems (IVHS) which are computer-assisted methods to manage highway infrastructures, synchronize traffic lights, measure traffic flow, to alert drivers to ongoing traffic conditions through electronic billboards and other innovations aimed at improving the quality and efficiency of road transportation systems for vehicles.

The California Air Resources Board (CARB) has been a leader in establishing standards for monitoring vehicle emissions. A recent CARB proposal, known as OBD-III, is the third generation of on-board diagnostic requirement, calling for an emissions regulatory agency to retrieve, remotely, diagnostic data from vehicles, thereby avoiding the need of a visit to a clean air inspection station. The proposal suggests an ultra low-power transponder on each vehicle which is capable of transferring data between the vehicle and a roadside receiver. Of course, in order for the OBD-III proposal to proceed, each vehicle must have a system capable of collecting and dispatching the requested data through the transponder. CARB is actively reviewing currently available technologies and is working with the telecommunications industry to see what future equipment is planned. The operating platforms tested thus far by CARB have been relatively cumbersome and have limited capability to be used for other data exchange needs in the future. There is interest in finding a platform that will be economical to operate in order to minimize the financial burden placed on the consumer to implement the proposal.

Moreover, it would be desirable for the chosen platform to be capable of doing more than just sending diagnostic information to a clean air agency. The industry is looking at

ways to utilize the tremendous business opportunities of reaching urban commuters in their vehicles while they devote several hours each day to their commute.

Vehicular traffic has become a major problem for urban planners. With land values skyrocketing and land-use issues becoming more of a concern, planners are looking for ways of getting more vehicles through existing commuter arteries as an alternative to expanding them. It is also known that the actual volume of traffic handled by a thoroughfare plummets when traffic becomes congested. Therefore, it would be desirable to have vehicles which are capable of exchanging data with themselves as a way to control such things as safe driving distances to avoid collisions and exchanging data with traffic monitoring systems to control such things as driving speeds.

It is therefore an object of the present invention to provide an improved platform for vehicular telemetry.

It is a further object of the present invention to provide an improved vehicular telemetry system which is relatively inexpensive, yet capable of exchanging a range of useful data with a data communications system.

It is still a further object of the present invention to provide a vehicle communications system in which the vehicles therein are each capable of communicating both with a data communications system and with themselves.

SUMMARY OF THE INVENTION

Briefly stated, the invention involves a method of exchanging data between a wired network and a wireless network, comprising the steps of

     a) providing at least two data links between the networks;

     b) measuring impedance on each data link; and

c) transmitting the data across the data link having the lowest impedance.

Preferably, the method further comprises the step of:

d) providing each of the networks with an IEEE 802.11 node, wherein one of the data links is established therebetween.

Preferably, the data links are wireless and a first of the data links is established on a Spread Spectrum radio frequency (RF) band. The data links may also comprise a satellite RF packet network or a terrestrial RF packet network. It is contemplated that other data links may become available in future as wireless data communications evolve.

In another of its aspects, the present invention provides a communications system, comprising:

a mobile communications network having a mobile node,

a fixed communications network having an access point,

a pair of alternative data links, each of which joins the mobile node with the access point, and

a switching unit for switching between the alternative data links to exchange data between the mobile node and the access point.

In one embodiment, the mobile communications network includes a plurality of vehicle-mounted mobile nodes wherein each is Internet addressable, for example under IPv6 protocol. Each mobile node and selected ones of the access points operate under the IEEE 802.11 standard. In this case, the data link joins each mobile node with at least one access point on a Spread Spectrum band. At least some of the access points are located adjacent a roadway.

Preferably, the system includes a measuring module for measuring impedance on each of the data links. In this case, the switching unit is operable to select the data link having the least impedance.

In still another of its aspects, the present invention provides a communications network for exchanging data between a plurality of vehicles, comprising a computing unit onboard a corresponding vehicle, each computing unit being operable in a first phase to broadcast enquiry messages in a region surrounding the vehicle, a second phase to receive reply messages from other vehicles in the region, and a third phase to exchange status messages with selected ones of the other vehicles.

In one embodiment, each computing unit includes an IEEE 802.11 node and exchanges data using an SNMP-derived protocol. Desirably, each node is Internet addressable, such as by the IPv6 standard for example.

In still another of its aspects, the present invention provides a vehicle comprising an onboard computing unit which is operable in a first phase to broadcast enquiry messages in a region surrounding the vehicle, a second phase to receive reply messages from computing units of other vehicles in the region, and a third phase to exchange status messages with computing units of selected other vehicles.

Preferably, the vehicle is operable in a fourth phase to exchange data with a remote site in the form of a network gateway, which routes communications between a wireless mobile data link and a non-mobile network.

In one embodiment, the computing unit includes an IEEE 802.11 node and can exchange data with other computing units using an SNMP-derived protocol.

In still another of its aspects, the present invention provides a hybrid communications system, comprising a wired network portion and a wireless network portion, each having a network connection node, at least two data link means between the

network connection nodes, and a switch means for enabling either of the data links for data exchange between the connection nodes.

Preferably, the system further comprises measurement means for measuring impedance on the data links, the switch means being responsive to the measurement means for enabling the data link having a lower impedance.

In yet another of its aspects, the present invention provides a vehicle communications system having a controller, a data pathway joining the controller with a plurality of vehicle components and means for establishing a data link with other vehicles within a given region surrounding the vehicle in order to exchange data therewith.

In still another of its aspects, the present invention provides an operational event-reporting system for use by a plurality of neighboring vehicles to support IVHS comprising a plurality of communication units, each onboard a corresponding vehicle to collect operational data from selected components thereof and to exchange data with the communication units of one or more of the neighboring vehicles.

Preferably, the system is capable of exchanging data related to the operation of the neighboring vehicles, for example, GPS position and heading, vehicle speed, braking or the like. Data of this kind can be useful for vehicle telemetry systems to provide such things as collision avoidance, for example.

In yet another aspect of the present invention, there is provided a method of exchanging data between a vehicle and at least one data exchange site, comprising the step of providing the vehicle with a transmitter and receiver capable of transmitting and receiving messages under the SNMP protocol. Preferably, the data exchange site includes a neighboring vehicle or an access point for a wired network, for example.

In one embodiment, the method further comprises the steps of:

- exchanging discovery signals with neighboring vehicles; and

- exchanging status data with selected ones of the neighbouring vehicles.

In yet another of its aspects, these is provided a system for transferring data between a vehicle and another data exchange site, comprising a pair of data link means, wherein at least one of the data link means has a varying signal impedance level and switch means for switching between the data link means so that the data is transferred on the data link means having the least impedance.

The Applicant's pending application, serial number 09/140,759 filed August 26,1998 entitled SYSTEM AND METHOD FOR PROVIDING MOBILE AUTOMOTIVE TELEMETRY discloses a system and method for automotive maintenance telemetry. The system functions on a client-server architecture enabling a remote client to request information from an onboard diagnostic (OBD) module in a vehicle, such as that commonly referred to as the Electronic Control Module (ECM). The OBD module performs the role of 'server' by being programmed to interface with the ECM, and with any other sources of diagnostic information and then communicates the data to a requesting client, such as OEM suppliers, dealers or regulatory agencies.

The location of the requesting client can dictate how the data is delivered. For example, in the Applicant's co-pending PCT Application PCT/CA98/00986 filed October 23, 1998 entitled TELECOMMUNICATIONS SYSTEM, the OBD module may select a path of least impedance to deliver the data to the client. For example, where the client is land-based, such as, for example an emissions regulatory body, the OBD module may deliver the data either through a conventional RF packet network (such as over a cellular phone connection) or through an RF packet network using a Hybrid network as described in the above mentioned PCT application. However, the requesting client may in fact be another vehicle traveling along the same roadway as the server vehicle and may request data for such things as vehicle speed, braking, position and the like. The OBD module may convey the data over a wireless data link such as over the band known as the "Spread Spectrum Band" as is described in the applicant's co-pending provisional application serial number 60/139,573 filed

June 17, 1999, entitled VEHICULAR TELEMETRY and as specified in the IEEE 802.11 standard.

IEEE 802 Standards Family

The IEEE 802 family of standards specifies the methods for implementation of local area networks (LAN's) using both wired and wireless media. The IEEE 802.11 standard specifies the medium access control (MAC) layer and three separate methods for implementation of the physical layer (PHY) as a wireless medium. IEEE 802.11 is intended to ensure inter-operability between multi-vendor equipment operating in wireless networks. As such, it is the basis for the interface specified herein enabling vehicular computing equipment to establish license-free data links with fixed stations.

The IEEE 802.11 standard specifies three different Physical layers, use of Infrared light, Direct Sequence Spread Spectrum and Frequency Hopping Spread Spectrum. The band utilized for the Spread Spectrum technique is ISM (Industrial, Scientific and Medical) RF band, which is free of regulatory licenses in most of the world. Communications in the Spread Spectrum involve a coordinated change in frequencies, either by a "Direct Sequence" or a "Frequency Hopping" format. Though the specific nature of these formats is not relevant for the purposes of the present invention, it is merely important to realize that they exist.

The IEEE 802.2 standard, called Logical Link Control (LLC), specifies a method for addressing and control of the data link; independent of the underlying medium, and is applicable to all types of LAN's defined within the IEEE 802 family. Both 802.11 and 802.2 are incorporated herein by reference.

The IEEE 802.11 does not[.] specify the handoff mechanism for a mobile node to roam from one Access Point to another. When both the IEEE 802.11 client and Access Points incorporate IPv6 implementations, including ND and RD, roaming clients are able to bind to (or to establish a data link with) the Access Points, where the latter take on the role of Foreign Mobility agents as defined in [3]. The Access Point acts as a mobility agent for the

roaming client. The Mobile IP specification therefore provides a solution to the lack of an IEEE 802.11 mechanism for coordination of roaming (handoff) between Access Points.

Automotive Telemetry protocol

In one embodiment, data is exchanged between vehicles using a protocol herein called "Automotive Telemetry Protocol" (or ATP) and is based on Simple Network Management protocol (or SNMP). The latter is commonly used in data communication networks to monitor and control switching equipment. SNMP is specified in [2], the contents of which are incorporated herein by reference. ATP is intended to function according to the same client-server model as SNMP, wherein the client issues the requests for information and the server issues the responses. Although the ATP makes use of the same formats of the requests and responses as SNMP, ATP implements a novel set of "object identifiers" which are required to encompass the OBD data requested, in contrast to the telecommunications equipment data exchanged in SNMP. For example, the object identifiers may, in this case, correspond to nodes on the Controller Automation Network (CAN) bus in the vehicle, such as the ABS system, emission control system and the like.

SNMP and its derivative defined herein, ATP, are efficient request-response mechanisms which require less bandwidth than Web-based data exchanges between client and server. The payload (i.e. the useful telemetry data) can be encapsulated within the maximum allowable frame sizes of the underlying data links. These protocols therefore do not require the overhead associated with fragmentation at the source, and properly sequenced reassembly of large messages at the destination.

1Pv6 and Mobile IP: Dynamic topology of the new Internet

The well known "Mobile IP" specification defines a protocol that enables IPv6 datagrams to be transparently routed to mobile nodes in the Internet. This specification is

provided in **Internet Engineering Task Force, Perkins, C (ed.), " IPv6 Mobility Support",** **March** 1995 [3], the contents of which are incorporated herein by reference.

By definition, a mobile node is one that can connect to the Internet through any one of a variety of different access points, called *mobility agents*. Each mobile node is registered with one and only one mobility agent, called a home agent. When a mobile node attaches itself to the Internet through an access point other than its home agent, the access point is called a foreign agent. The Mobile IP protocol incorporates a mechanism for mobile nodes, when they are attached to a foreign agent, to register a "care-of-address" with the home agent. Thus, datagrams routed to the mobile node through the home agent can be re-routed to reach the mobile node at its current network location.

When a mobile vehicle is already equipped with radio-modem technology that provides a unique address on a wireless network, it is possible to assign a unique Internet address that can be reached through an IP router between the wired Internet and the wireless network. This is described in the Applicant's co-pending PCT Application PCT/CA98/00986 filed October 23,1998 entitled TELECOMMUNICATIONS SYSTEM. This represents a static Internet topology because, although the vehicle is mobile, the IP router through which it is reached never varies. The topology of the wireless network itself is dynamic and supports the roaming required for a vehicle to establish contact with the network through different base stations and regional switches. However, at the IP level, this dynamic topology is not visible.

In contrast, the Mobile IP extension to the IPv6 specification allows for a dynamic network topology. It lends itself to the task of enabling communication from the Internet to a mobile vehicle through different foreign mobility agents. In the context of vehicular mobility, the role of mobility agent can potentially be adopted by any Internet node that has the ability to dynamically create a data link with a vehicle. To date, the most efficient means available by which such data links can be quickly established are defined by the IEEE 802.11 specification for wireless LAN's (Local Area Networks).

A data link can be established between a mobile IEEE 802.11 node, implemented in the vehicle, and any fixed IEEE 802.11 node, called an *Access Point*, provided that both nodes incorporate full implementation of the IPv6 protocols, specifically the Neighbor Discovery protocol, (hereinafter referred to as ND) and the Router Discovery protocol (RD). ND and RD are specified in **Narten, T., Nordmark, E:, and W., Simpson,"Neighbor Discovery for IP Version 6 (Ipv6)", RFC 1970, August 1996.**[5], the contents of which are incorporated herein by reference. For every interface to a datalink implemented in an Ipv6 node, in this instance a wireless IEEE 802 datalink, ND is required to ensure that neighbors, defined as other nodes which are "on-link" (i.e., capable of communications on the same datalink) can be dynamically identified as they appear. This is accomplished through the use of periodic broadcasts on the wireless medium, called Neighbor Solicitations, to which any recipient of the broadcast is required to respond, in such a way as to enable the broadcaster to identify the responder with a unique IPv6 address. An implementation of ND typically maintains a table of neighbors that dynamically changes as each new cycle of neighbor solicitation either reveals a new respondent or loses, through lack of response, a (previously) existing neighbor. RD is a specialization of ND, ensuring that on-link nodes capable of routing IP datagrams to other sub-networks, can be discovered.

Thus, the vehicle communications system, according to one embodiment of the present invention, is capable of handling the Mobile IP protocols over an IEEE 802.11 data link and, as a consequence, is capable of delivering vehicular diagnostic data under the requirements of OBD-III and of exchanging a wide range of data, including ecommerce transactions and the like, as well as data needed for such things as Intelligent Vehicle Highway Systems.

According to one aspect of the present invention, each vehicle has one of a number of Hybrid Network Radios (as described in Applicant's PCT patent application PCT/CA98/00986) which can effectively communicate with one another using the Mobile IP protocol over one or more wireless LAN's. In this particular case, then, Internet-addressable vehicles may roam between wireless LAN's and still be in the network.

Ad Hoc Network

By making the vehicular computers Mobile IP-enabled as described in utility patent application 09/140,759 filed August 26, 1998 (entitled SYSTEM AND METHOD FOR PROVIDING MOBILE AUTOMOTIVE TELEMETRY), each vehicular system may be connected to the Internet through the IEEE 802.11 data link. When two or more vehicular computer systems are equipped with IEEE 802.11 interfaces and where each operates on the same frequency changing format, that is by using either Direct Sequence Spread Spectrum or Spread Spectrum Frequency Hopping, they can then communicate amongst themselves and thereby create an "ad hoc" network between them. The so-equipped vehicular systems can now support IP Neighbor Discovery, which enables all vehicles within range to recognize each other as "on-link" IPv6 nodes, provided that the adjacent vehicular systems are also compliant with IPv6. This means that useful information may be exchanged between adjacent vehicles by the use of Spread Spectrum frequencies. Therefore, the same UDP/IP mechanism, used to permit telemetry traffic to be encapsulated in IPv6 datagrams from any vehicle to a fixed-location host, can be used to permit telemetry traffic to be exchanged between vehicles.

This ad hoc network also enables mobile vehicles within range of each other to establish a "cluster intelligence", which is defined, within the context of the present invention, as an infrastructure for interactive vehicular control based on the same request/response telemetry architecture described in utility patent application serial number 09/140,759 filed August 26, 1998 (entitled SYSTEM AND METHOD FOR PROVIDING MOBILE AUTOMOTIVE TELEMETRY).

In one embodiment, the system comprises the following components:

(1)   Hybrid Network Radio, as specified in [4], supplemented by:
        (a)   Wireless LAN interface compliant with:
            (i)   IEEE 802.2
            (ii)   IEEE 802.11 interface

 (b) IPv6 modules including:

   (i) IPv6

   (ii) IVMPv6

   (iii) IP Neighbor Discovery and Router Discovery

   (iv) Mobile IP

(2) IEEE 802 Access Point as an IPv6 Router

(3) *Cluster Intelligence* Module

The cluster intelligence module is intended to provide a means by which intelligent Vehicle Highway Systems (IVHS) can be implemented without the need for electronic wiring of the highway infrastructure. Cluster intelligence is based on the establishment of an *ad hoc network* connecting vehicular Hybrid Network Radios. Whereas the primary goal of the Hybrid Network Radios is to enable least-cost IPv6 communications of telemetry data required by environmental regulations, an ad hoc network among and between Hybrid Network Radios provides a platform on which vehicles can transmit real-time operational information to each other.

As a result, in those instances where the aim of IVHS is to control the spacing and speed of vehicles on highways, and therefore the volume of vehicular traffic flow, cluster intelligence offers a low-cost alternative to the conventional ideas proposed for highway infrastructure upgrades.

Figure 7 shows the classic relationship defined in traffic engineering between speed and volume on a road link. There is an optimum point along this curve where the volume is maximized. The speed at this point is defined as the "free flow" speed. Below this speed, traffic flow is congested. Above this speed, the spacing between vehicles required for safety results in profligate use of the roadway. At any point along the curve, the volume-speed relationship represents the most efficient inter-vehicle spacing, given the braking distance required for safety, which can be achieved.

In one embodiment of cluster intelligence, the peer-to-peer telemetry architecture of [1] supports the ability of vehicles to adapt their speeds in accordance with the optimal volume-speed relationship. ATP used between vehicles enables each one to determine[;]:

(a) The distance(s) between it and the vehicle(s) immediately ahead of it (using GPS position and heading reports).

(b) The speed(s) of the vehicles immediately ahead of it.

(c) Application of brakes.

This information provides the enabling technology for all vehicles to engage in a cooperative effort to maximize traffic flow on electronically enhanced highways.

The tern "Impedance" used herein is intended to be a measure of the "costs" of sending a datagram across a data link. This cost can include the monetary charges associated with the transmission of data across a wireless data link and are typically imposed by the operator of the wireless data network, as well as other factors such as, for example, the size of packet and the time of day, which of course will change over time. As is described in the PCT Application serial number PCT/CA98/00986 filed October 23, 1998 entitled TEI,ECOMMUNICATIONS SYSTEM, the Impedance governs the functionality of the RF path switch. As impedance changes, the output of the RF path switch (i.e. the routing decision) can change. The sections entitled Error Reporting and Airlink Status Reporting describe the mechanisms whereby changes in impedance are reported to the RF path switch module.

BRIEF DESCRIPTION OF THE DRAWINGS

Several preferred embodiments of the present invention will be provided, by way of example only, with reference to the appended drawings, wherein:

Figure 1 is a schematic view of a vehicle communications system;

Figure la is a schematic view of one aspect of the vehicle communications system of figure 1;

Figure 2 is another schematic view of the vehicle communications system of figure 1;

Figure 3 is a schematic view of one segment of the vehicle communications system of figure 1;

Figure 4 is a schematic view of another segment of the vehicle communications system of figure 1;

Figure 5 is a schematic view of still another segment of the vehicle communications system of figure 1;

FIG. 6 is schematic representation of a system in accordance with one embodiment of the present invention; and

Figure 7 is plot of traffic volume versus speed on a road link

<u>DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT</u>

Figure 1 illustrates a communications network for exchanging data between a plurality of vehicles, including vehicles 10 and 12 on a highway shown at H. Each vehicle has a computing unit 10a and 12a, the latter of which is shown schematically in figure la. Each computing unit has a processor 10c which is connected via a serial port to a GPS unit 10d which is capable of receiving satellite GPS signals, an IEEE 802.11 Spread Spectrum unit 10e capable of broadcasting and receiving data over a Spread Spectrum data link, a cell packet data unit 10f capable of broadcasting and receiving data over a cell packet data network and a memory unit 10g. If desired, the components of the computing unit may be chipset as specified in U.S. provisional application serial number 60/148,270, filed on August 11, 1999 and entitled VEHICULAR COMPUTING DEVICE.

Referring to figure 1, each computing unit 10a, 12a broadcasts ND and RD messages in a region surrounding the vehicle as shown by the circles 10b, 12b. In the example shown in figure 1 three other similarly equipped vehicles labeled 14a to 14c are all within the region 10b and therefore are capable of receiving the broadcast enquiry messages from the vehicle 10. The vehicles 14a to 14c issue reply messages which are received by the vehicle 10. Similarly, vehicles 14b to 14f are within the region 12b of the vehicle 12 which in turn receives reply messages from them. These messages may include such things as vehicle speed and GPS information as well as status indicators such as acceleration or braking. In this manner the computing units 10a, 12a are able to determine the position and movements of neighboring vehicles.

Thus, the number of vehicles in the corresponding region for each vehicle will change over time with the traffic pattern. In this case, the computing unit for each vehicle can retain status data for each target vehicle while the vehicle is in the region and then erase the data for those vehicles that have left the region. The memory unit 10g can have allocations for storing data for each vehicle while the processor can manipulate the data to determine if any action needs to be taken. The processor also receives data from the ECM 10h which can include such things as emissions, braking, acceleration, speed and the like, that is, any function of the vehicle which is being electronically sensed, monitored or measured. The processor may also be coupled with a braking override 10i or other override 10j for controlling the vehicle if necessary.

Located along the highway are a number of access points which are routers to a fixed communications network, in this case Spread Spectrum base stations. One of the access points is shown at 16. The access point 16 issues router advertisement messages with a region shown by the circle 16a. Therefore, vehicle 12, in the instant of time represented by the figure 1, receives the advertisements. In this example, the vehicle computing units 10a and 12a as well as the access point 16 are IPv6 addressable. Therefore, the vehicle 12 and the access point 16 may then exchange data which may include Internet email and the like. The access point 16 may also convey status request data from a clean air regulatory body to the

vehicle 12 which may then return the status data to the regulatory body through the access point 16 if the vehicle is still in its region.

Located near the highway is an RF packet network base station 18 such as a relay tower or the like which broadcasts on a data link such as a proprietary RF packet network, for example that known as the MOBITEX network, or the like. This is a different data link from that Spread Spectrum data link operating at the access point 16. The computing units exchange data with the station 18 via the cell packet data unit 10f.

The GPS information from the neighboring vehicles may, for example, include Differential GPS (D-GPS). In the latter cases, the vehicle may more accurately measure the position of neighboring vehicles, relative to a reference GPS position which may be broadcast, for example, from the access point 16.

Global System

Figure 2 shows the overall system architecture. As will be described, Figure 2 illustrates how the IEEE 802 data link is incorporated into the hybrid mobile packet network and shows the path of Mobile IP communications between a mobile node shown at 10 and its home mobility agent, i.e., the Hybrid Network Gateway 230. Mobile node 10 is an embedded vehicular computing device functioning both as an OBD server [1] and as a Hybrid Network Radio [2]. The Hybrid Network Radio functionality is implemented through the interface 40 to the hybrid mobile packet network 250.

Fixed node 16 is a wireless communications base station implemented in accordance with the definition of a "foreign (mobility) agent" contained in [3]. Mobile node 10 and fixed node 16 share the same IEEE 802 wireless data link 15, which, from the perspective of the mobile node 10 and as will be described further below, is integrated as a "zero-cost" data link in the interface 40 to the hybrid mobile packet network 250. Fixed node 16 may be, for

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instance, an embedded computing device permanently installed near a roadway and connected to a data communications network 210 via a stationary (non-mobile) backbone 220.

When a mobile node 10 comes sufficiently within range of a fixed node 16 to establish an IEEE 802 data link, Internet traffic, in the form of IP datagrams, may flow from the vehicle to any address in the Internet. This is called "mobile-originated" traffic. "Mobile-terminated" traffic can only reach the vehicle once the Mobile IP "care-of address" registration has been completed. This procedure; specified in [3], allows the mobile node to notify its "home (mobility) agent" that it can be reached through the foreign (mobility) agent embodied in the fixed node 16. As a foreign (mobility) agent, fixed node 16 is, by definition, an IPv6 router.

The home mobility agent for mobile node 10 resides in the Hybrid Network Gateway 230. A Hybrid Network Gateway (HNG) is the stationary equivalent of a Hybrid Network Radio and is defined in [2]. HNG 230 has an abstract interface 240 to the hybrid mobile packet network 250, through which it can route Internet traffic to a mobile node. In order to ensure least-cost routing to a mobile node that has registered fixed node 16 as its care-of-address, interface 240 must also incorporate the data link associated with stationary backbone 220. This extends the hybrid mobile packet network to include a stationary data link.

In other words, the system has the capacity to carry out least-cost transfer data between the Hybrid Network Gateway 230 and the mobile node 10 in one of three routes:

i) via the data link 15, the fixed node 16, the data link 220 and the stationary non-mobile data link 210; or alternatively

ii) through the hybrid mobile packet network 250, which itself can provide least cost switching between

    a) a satellite Packet Network; or
    b) an RF Packet Network..

Ipv6 Communication Protocol Stack

The IPv6-based communications software infrastructure for a telemetry system in accordance with this example is shown in Figure 3. Figure 3 is a representation of the Hybrid Network Radio incorporating interfaces to an arbitrary number of RF packet networks, including an interface to a wireless IEEE 802 data link, integrated into a single abstract data link as specified in [4]. Figure 3 also shows the relationship between the Hybrid Network Radio and an IEEE 802.11 Access Point incorporating an IPv6 router implementation. In this scenario, mobile-originated Internet traffic (datagrams emanating from the Hybrid Network Radio) can be routed through the access point or alternatively through the hybrid mobile packet network 250 depending on 'cost'. Mobile node 10 is an IPv6 (Internet) node consisting of a protocol stack 20 in accordance with the definition of a Hybrid Network Radio provided in [4]. Fixed node 16 is an IPv6 (Internet) router consisting of the router-specific equivalent of protocol stack, labeled 21. The components of protocol stack 20 are:

(i) a combined RF packet network 30 that unifies all the wireless data links available to mobile node 10 into a single abstract data link capable of least-cost switching;

(ii) an IPv6 module 60, in accordance with [6], the contents of which are incorporated herein by reference;

(iii) an ICMPv6 module 70, in accordance with [7] the contents of which are incorporated herein by reference, that provides the assembly and parsing mechanisms for the specific datagrams required by ND;

(iv) a Neighbor Discovery (ND) module 80, in accordance with [5], that enables mobile node 10 to dynamically discover other "on-link" mobile nodes, i.e., other vehicles capable of communicating on the same IEEE 802.11 medium; and

(v) a Router Discovery (RD) module 90, in accordance with [5], which enables mobile node 10 to discover dynamically IPv6 router 16.

Both the ND and the RD protocols require the broadcasting of, respectively, neighbor and router advertisement datagrams, defined in ICMPv6. These datagrams are sent to the

interface 40 to the combined RF packet network 30. Broadcast datagrams can only be transmitted on data links that are broadcast-enabled. Typically, wide area RF packet networks do not support broadcasting, although they often allow multicasting to selected groups of mobile subscribers. Since IEEE 802.11 depends on broadcast frames to establish the data link, it should identify itself to interface 40 as broadcast-enabled, whereas all other RF packet networks incorporated in the combined packet network 30 should report that they are not broadcast-enabled. The intelligent switching mechanism of this interface, which ensures that datagrams are transmitted over the least-cost data link, will therefore switch all mobile-originated broadcast datagrams over the IEEE 802.11 data link.

In case of overlapping of the coverage areas of two or more Access Points, a mobile node may receive router advertisements from more than one fixed station, in response to its broadcast of router solicitations, providing it with alternative on-link routes to use for outbound datagrams. Contrary to the recommendation in [5], mobile nodes should avoid the use of router and neighbor solicitation datagrams, in order to minimize the amount of contending traffic on the data link. Both neighbor and router discovery should rely primarily on unsolicited neighbor and router advertisements.

Registration of the "care-of-address" provides a means for requests from the OBD telemetry client to reach a mobile node via the foreign mobility agent, which, by definition, is an IEEE 802 access point. The impedance values of these requests can be set such that the mobile-terminated ATP traffic that would otherwise incur costs traveling over RF packet networks, can be deferred until the "care-of-address" is registered with the home address.

Cluster Intelligence

The cluster object as an ATP client is a specialization of the generic SNMP client using the UDP/IP protocol. The ATP allows for message passing to the cluster object.

The establishment of an IEEE 802.11 ad-hoc network as a "mobile cluster" in accordance with the present example is shown in Figure 4. Mobile node 10 incorporates the User Datagram Protocol (UDP) module 100 and the ATP module 110. An equivalent mobile node 11, with equivalent UDP and ATP modules 101 and 111, respectively, can interact with mobile node 10 such that the automotive behavior of 11 is known to 10. This is accomplished through the mechanism of an ATP request issued by 10 to 11 and an ATP response from 11 to 10.

The interaction between any two mobile nodes is managed by a "cluster", which is an active object that registers with the ATP module for reports from neighboring vehicles. Cluster module 120 has container 130 of neighbors, or more precisely, "images" of neighbors. These neighbors are placed in the container when detected by the ND mechanism operating over the IEEE 802.11 data link, as shown in Figure 4. By propagating the discovery mechanism in ND module 90 upwards through the UDP/IP stack, Node 11 becomes a member of Node 10's cluster when the ATP module 110 signals the cluster module 120 hat a new neighbor has appeared. (The whole process can be repeated for mobile node 12, which becomes a second neighbor of node 10).

Registration of neighbors discovered through the ND requires an implementation of Ipv6 that can be asynchronously notified of ND, which requires a "callback" method of IPv6 to be invoked when the neighbor's response to a solicitation request is being processed. The conventional processing of such a response is simply to update the cache of on-link neighbors known for that interface. However, the requirements of cluster intelligence are that dynamic neighbor identification propagate upward from the subnetwork layer to an application port of the UDP/IP protocol stack.

In this example, cluster communications over wireless data links is intended to take place only over the license-free Spread Spectrum band. The cluster object itself has "no knowledge" of the fact that there are alternative radio paths between vehicles. However, when the cluster asks each new neighbor to transmit GPS position reports and automotive events in which it is interested, both the requests as well as the responses will travel only over zero-cost links - which are precisely the same links over which the ND operates. In other words, by virtue of the least-cost mechanism described in [4], a license-free wireless data link will always be the data

link over which the ND datagrams are transmitted. ND can and should be configured such that its maximum acceptable impedance level can only be supported by the license-free links. ND will therefore only discover neighbors that are on the license free links and cluster traffic that follows from this will travel only over these links.

Provided that an implementation of cluster 130 is compliant with the requirements for the interface to the module ATP 110, already specified in [1], the internal behavior of the cluster may vary depending on the design objectives and implementation style for a specific vehicular device. The precise design of the methods (behavior) or the specification of other methods intended to process (and act on) information reports from neighboring vehicles is not within the scope of the present invention.

Process Architecture

Figure 5 illustrates the process architecture of the device comprising the mobile node. ATP client process 300 is part of the cluster intelligence module. Figure 5 illustrates the architecture of the processes, running on top of the UDP/IP stack, that provide all of the functionality of the system. These processes are:

(i)   an OBD process, with the behavior of an ATP server;

(ii)   a Cluster Intelligence process with the behavior of an ATP client;

(iii)   a Mobile IP process, with the behavior specified in [3]; and

(iv)   a diagnostic data acquisition process.

ATP is registered with UDP module 330 through the *application port* 305. Similarly Mobile IP process 310, which is responsible for registration of care-of-addresses (i.e., addresses of foreign mobility agents) with home mobility agents, is registered with UDP module 330 through the application port 315. The ATP server process 320, registered with UDP module 330 through port 325, provides access to the Diagnostic Information data Base (DIB) 340. This data

base, similar to the Management Information data Base (MIB) used by SNMP (from which ATP is derived), contains all of the on-board diagnostic information obtained from the data acquisition processes 350 (Analog and digital signal processing), 360 (CAN-bus data processing) and 370 (GPS receiver data processing).

Whereas the present invention does not limit the scope or characteristics of possible cluster implementations, the behavior recommended for effective use of the ATP to implement cluster intelligence within each vehicle is described by the pseudo-code below. The cluster is defined as an object that owns an ATP client process with a set of methods corresponding to the handling of each of the possible messages that could be received through the ATP.

The cluster's ATP client process would be:

ClusterProcess ()

{

    while(TRUE){

        pointer_ event_object = Wait _Queue_ Event_ Signalled_By_ ATP();

        pointer_ event_object->Handler(); // behavior of event object

        destroy_ event(pointer_ event_ object-)

    }

}

The cluster process blocks on an event queue, registered with the ATP, to which the ATP can append events relevant to the cluster process as they occur. These events are removed from the queue and processed on a first-in first-out basis. All events are treated as objects derived from a common base class within a virtual "handler" method, the internal behavior of which varies for each type of event. The handler method of the event is invoked by the cluster process when the event is removed from the queue.

The primary type of event which the ATP should signal to the cluster is a GPS position report from a neighbor. This implies, of course, that all nodes on the ad-hoc IEEE 802.11 network should broadcast GPS position reports. Other on-link nodes receiving these broadcasts

should propagate the reports upward through the protocol stack to the ATP, which should signal an *Event GpsReport* to the cluster. *Event_GpsReport_Handler ()* is the method invoked when *the GpsReport* signaled by the ATP is removed by the cluster process from its queue. The inputs to this method are:

(i)   *ID_Remote_Vehicle* - which should be the unique IP address of the vehicle;

(ii)   *GpsPosition* - which is a latitude-longitude coordinate pair, determined by the GPS receiver of the remote node and contained in the payload of the UDP segment received from the remote; and

(iii)   GpsHeading- which is a heading determined by the GPS receiver of the remote node and contained in the payload of the UDP segment received from the remote.

Event_GpsReport_Handler (ID_Remote_Vehicle, GpsPosition, GpsHeading)

{

Remote_Vehicle = GetRemote(ID_Remote_Vehicle);

Proximity = CompareGps(Remote_Vehicle, GpsPosition, GpsHeading);
If(Proximity){

AtpRequest(Remote Vehicle, speed, frequency, duration, amplitude);
AtpRequest(-Remote_Vehicle, foot brake, 0, 0[.], 0);

}

}

Event_GpsReport_ Handler carries out the following functions;

(i)   Invokes the private function *GetRemote* using the *input ID_Remote_Vehicle.* (The term *private* signifies that the function is usable only by the cluster module and is not accessible to "external" software modules). This searches the cluster's container of remote vehicles for the object matching ID_*Remote_Vehicle;*

(ii) Uses the private function *CompareGps* to determine whether this vehicle is within a specified distance threshold. This function takes as inputs:

(a) Pointer to the Remote Vehicle object; and

(b) the new GPS position and heading.

The GPS position and heading of the remote vehicle are compared to the position and heading of the "local" vehicle, The "local" position and heading are maintained in the DIB (diagnostic information base). Since the ATP is a peer-to-peer protocol, cluster intelligence request/response exchanges can be symmetrical. The DIB can therefore be used by the ATP client to obtain GPS information for comparison with reports from remote nodes, as well as by the local OBD server to respond to cluster intelligence requests from remote nodes.

The output of *CompareGps* a boolean variable (*Proximity*) indicating whether ATP requests to this remote are warranted because the vehicle is within a specified distance threshold to require preventive measures if there is a sudden change in speed. Since the implementation of cluster intelligence is not within the scope of the present invention, the internal algorithm of CompareGps is not defined here. However, it should be noted that any implementation of CompareGps must account for margins of error in the accuracy of the GPS receiver where the remote position report originates. Furthermore, it may not be possible to distinguish between several remote vehicles moving in parallel in different lanes ahead of the "local" vehicle so that the identity of the vehicle directly in front may remain indeterminate. The cluster intelligence decision algorithm may have to assume that all of these vehicles are equally important to monitor.

If Proximity is TRUE, then ATP requests can be issued to the remote node's OBD server, the responses to which enable the cluster to provide decision support to other intelligent modules within the complete automotive system. A minimum set of requests could consist of speed reports, at values of frequency and duration established by the owner of the cluster, (i.e., one of

the aforementioned automotive modules), and of notifications for the application of the foot brake.

A mobile automotive telemetry system in accordance with the present invention is shown schematically at 610 in FIG. 6. System 610 comprises a diagnostic means 615 for monitoring the operational functions of the vehicle in which system 610 is installed and generating operational information. The generated operational information may be stored in a memory 620 until required. Both diagnostic means 615 and memory 620 are in communication with a server 625 which ultimately controls the operation of system 610.

Server 25 can communicate with a remote client 630 via a data link 635. To this end, server 625 comprises a means (640) to receive a request for information from remote client 630; a means (645a, 645b) to retrieve the generated operational information from memory 620; and a means (650) to transmit the retrieved generated operational information to remote client 630. Server 625 is a processor which is programmed to respond to requests for information from remote clients and to respond to control commands.

Diagnostic means 615 may be a conventional, computer-based OBD module which monitors various operational functions of the vehicle in which system 610 is located. Diagnostic means 615 may, for example, monitor exhaust emissions, fuel use, ignition timing, engine temperature, speed and/or distance traveled. Diagnostic means receives inputs from the various vehicle sites via a plurality of communication lines 660 and, after interpreting the inputs and generating formatted operational information, passes the operational information to memory 620 via communication line 665. Diagnostic modules suitable for use in the present invention are known in the art and are referred to as Electronic Control Modules (ECM) or Electronic Control Units (ECU). The specifications for the diagnostic modules may be found in Society of Automotive Engineers, "On-Board Diagnostics for Light and Medium Duty Vehicle, Standards Manual" 1997 Edition, the contents of which are incorporated herein by reference.

Memory 620 may be any conventional computer memory, the size and operation of which will be dependent on the nature of the operational features of the vehicle a user wishes to

monitor. The choice of suitable memory is believed to be within the purview of a person of skill in the art. In a presently preferred embodiment of the present invention, system 610 comprises a memory 620 which includes 32 k of nonvolatile RAM and a configurable amount of additional RAM, allocated at run-time from the host processor system. Memory 620 receives the operational information, generated by diagnostic means 615, via communication line 665 and stores the operational information. Memory means 620 is in communication with server 620 and is capable of receiving instructions from server 625 and sending information to server 625 via communication lines 670a and 670b, respectively. As will be apparent to a person of skill in the art, communication lines 670a and 670b may be replaced by a single communication line if the appropriate communication protocol is used.

Server 625 acts as a gateway between remote client 630 and diagnostic means 615 and eliminates the requirement that remote client 630 has knowledge of the specialist OBD protocols of diagnostic means 615. Server 625 in effect acts as a "universal translator", allowing a remote client to interact with any diagnostic means of any vehicle. One way of achieving this end is through the implementation of a request/response protocol which acts as a proxy for the corresponding OBD protocols. Under this type of protocol, an abstract request from the remote client which is received by the server is mapped to the corresponding request under the specialist OBD protocols and is then transmitted on the diagnostic means or memory, as appropriate. In the other direction, the responses returned by the diagnostic means or memory to the server are then mapped to an abstract response which is sent back to the client.

Such request/response protocols are known in the art and include, for example, IAS protocol for infrared links and UDP/IP protocol for wide area network communications.

Data link 635 may be any conventional communication link, including, for example, telephony (wired and mobile wireless), specialized mobile radio (SMR), infrared and satellite (both low earth orbit (LEO) and geosynchronous). Server 625 may be provided with the hardware and operational protocols necessary for communicating with remote client 630 by a variety of means, thereby not restricting communication to a remote client having one particular

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type of data link. Providing server 625 with a plurality of communication protocols aids in making the system of the present invention universally acceptable.

In a presently preferred embodiment, server 625 is provided with infrared data link capabilities. An infrared data link between the server and the remote client provides a local wireless method of acquiring data from an OBD module. It therefore removes the need for the client's equipment to incorporate a system-compatible connector (i.e, an OBD-connector as specified by the SAE) and to be physically joined by a cable in order to communicate with the system.

When, for example, the client is test equipment in a garage, the use of an infrared data link renders possible the development of service bays where information can be transferred almost instantaneously from the vehicle to the service technician's computer without requiring the customer to get out of the vehicle. The infrared connection may be achieved by attaching a serial infrared connector to a serial port on the server and by ensuring that there is an unobstructed path for IR transmission between the LED's of the infrared connector and that of the service technician's computer.

As will be apparent, the reliability of an infrared data link is improved with the implementation of a robust protocol which detects transmission errors and avoids collisions by operating in a half-duplex fashion. Such protocols are known and have, for example, been implemented by computer and software manufacturers for incorporation in consumer electronic products such as micro-computers, modems and cellular phones (i.e. the IrDA stack). Suitable protocols are described in Infrared Data Association, "Serial Inared Link Access Protocol (IrLAP)", Version 1.1, June 1996 and Infrared Data Association, "Link Management Protocol", Version 1.1, January 1996, the contents of both of which are incorporated herein by reference.

Through compliance with these infrared protocols, the server achieves a goal of rendering client test equipment independent of the OBD protocols. Accordingly, any micro-computing equipment which is infrared-aware, such as a desk-top, notebook or palm-top (Personal Digital Assistant or PDA) can effectively become a remote client.

In an alternative embodiment, the infrared data link may be replaced or enhanced by incorporating mobile wireless data links, coupled with the UDP/IP infrastructure for peer-to-peer client/server exchanges over a wide area network. This adaptation of the system extends the range of the services offered by the server beyond its capabilities with only the infrared connector and data link. The principles described in the previous sections remain the same, with the exception that access to OBD information no longer requires that the vehicle be moved within infrared detection range (typically 2-5 meters) of the test equipment. The vehicle can be in any location which is reachable on the Internet, via a mobile data link.

The system of the present invention may further comprise a means to transmit generated operational information to a remote client, in the absence of a request from the client, when the generated operational information satisfies predetermined criteria. Such transmissions of the generated operational information implies that server 625 effectively becomes a client with respect to a remote site which is capable of logging the transmission. This functionality can be achieved by utilizing the peer-to-peer communication architecture described above and is useful in, for example, alarm/emergency situations.

If, for example, while monitoring the exhaust emissions of a vehicle on the road, the level of carbon monoxide in the exhaust gases exceeds a predetermined level, the diagnostic means can communicate this information directly to server 625 via communication line 675. Server 625 can then transmit an alarm report to a remote site advising of the problem. This report can be transmitted in real-time, allowing the problem to be dealt with immediately, rather than having to wait until the vehicle undergoes routine servicing and diagnosis, days or even months after the problem has first come to light.

It is envisioned that the threshold values for alarms, as well as the frequency and duration of the alarm message, can be configured either directly at the server during installation or servicing, or by using remote commands from the client.

The system described herein may also incorporate Internet access technology for the drivers or passengers. The existing method of Internet access for individual personal computers (PC) is well-known. The PC establishes a serial link with a computer which has a permanent Internet (IP) address. The latter computer, for the purposes of this description, can be called a gateway. The serial link is physically either a direct cable connection or via a telephone circuit, using modems at both ends of the link. The PC does not have a permanent IP address. It is assigned a temporary IP address by the gateway for the duration of the connection. Therefore, if the link is maintained via a telephone circuit, then the connection automatically terminates when the circuit is dropped and the temporarily assigned IP address ceases to be valid.

One of the conventional methods of Internet access from a vehicle follows the technique described above, using an analog cellular phone and a cellular modem. By connecting the PC to the cellular modem, the driver/passenger can obtain a temporary IP address in the same fashion as with wired telephony.

Another method of Internet access from a vehicle is a technology called Cellular Digital Packet Data (CDPD), which is a form of packet-switching overlaid on the existing analog cellular infrastructure in the United States. CDPD operates with a portion of the bandwidth of the analog cellular system and provides a multiple access data link technology within each cellular base station's territory of coverage. However, contrary to the method already described, the network architecture of CDPD also allows each access device (CDPD modem) to have its own permanent IP address. Therefore, no dial-up connection is required to establish the presence of the PC on the Internet. It suffices for the PC to be connected to the CDPD modem (which is typically in the form of a credit-card style PCMCIA card) for any Internet traffic from another location to reach the PC.

IP V6 is a new version of the Internet Protocol. One of the design objectives of IP V6 is to enable portable computing devices (notebooks, palm-tops, etc.) to have permanent IP addresses which can be reached regardless of where the portable device is physically connected to the Internet. Therefore, the device could be connected, at different times, to both an office LAN (Local Area Network) as well as a residential LAN, without requiring manual intervention

by a network administrator in either LAN to ensure delivery of Internet traffic. This is achieved by ensuring that both LAN's have at least one node (computer) which acts as a "Mobility Agent". The Mobility Agent incorporates software which implements IP V6 and related protocols. The purpose of the mobility-related functions in this software is to ensure that roaming computing devices are automatically "discovered" when they establish a link to the Mobility Agent and that the rest of the Internet is informed of the new path which must be used to route traffic to the roaming device. Only those routers in the Internet which have been upgraded to support IP V6 will participate in this function.

A Mobility Agent can reside in a mobile environment as well as a fixed LAN. This scenario is a distinct departure from the existing models of Internet access already described. A mobile Mobility Agent, installed in a vehicle in the form of a mobile computer, can effectively "host" any IP V6-enable portable computing device, provided that it has a wireless data link to a network which is capable of routing packets on the Internet, such as CDPD. The implication is that if a vehicle is equipped with a Mobility Agent using, for instance, CDPD, then any portable device which a driver or passenger wishes to use in the vehicle to obtain access to the Internet does not also need the CDPD modem. It only requires the IP V6 software.

In order to equip any vehicle with IP V6 support, a hardware platform is required to host all of the required protocols and to provide the data links for portable devices trying to connect to the Mobility Agent. In order to support the SAE diagnostic test modes in the remote fashion described herein, the server contains all of the components which will also allow it to function as a mobile Mobility Agent.

It is envisioned that the Infrared port (and IrDA protocols), which is primarily useful for OBD diagnostic test modes while the vehicle is stationary and being examined, can "double" as an in-vehicle wireless point of entry to the internet for portable devices operated by the driver/passengers.